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ABSTRACT

This report considers one school's approach to science education, examining in particular the development of a two-semester required unified science course. Designed to be useful to all students and applicable to all areas of science, the course is characterized by a high degree of teacher teamwork, as in developing instructional materials. Science teachers organized instructional units around key concepts, process skills, natural phenomena, and science-related problems and identified target objectives for each unit. The teacher-developed course is inexpensive and flexible, easily accommodating timely themes. A full description of Rex Putnam High School's science offerings is given, including course descriptions from the school catalog. Pretest and posttest assessments indicate statistically significant increases in process skills measured, with no significant decrease in skill competencies throughout students' remaining high school years, whether or not they elect additional science courses. Teachers attribute the popularity of elective science courses to effective preparation in the required sequence. The process of teacher development of local programs is cited as the key to successful implementation, and replication of the unified science curriculum in other schools is discussed. Appendixes include a list of key concepts and skills and some considerations for local science curriculum development. (MJL)

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Lois J. Rawers
David C. Cox

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Preface

Concern over the quality of science education in the United States is registered almost daily in newspapers, in magazines, and on television. While much of that criticism is well grounded, this Bulletin tells the story of an Oregon high school science program that should reinstill optimism for science education and faith in science educators.

Science teachers at Rex Putnam High School in Milwaukie created their own curriculum and materials for the state-mandated year of science instruction. The chapters that follow detail its development, components, impact upon the overall science program, and means by which it can be replicated in other settings.

The Oregon School Study Council is indebted to Dr. David Cox, science coordinator and teacher at Rex Putnam High School, for contributing the characterization of Putnam's required year of science curriculum in the chapter "Description of Science Offerings." This section is adapted from Cox's work, "Local Curriculum Development for Competency Based Education," originally published by the Goal Based Education Program at the Northwest Regional Educational Laboratory. We are grateful to NWREL for their kind permission to utilize this material.

Lois Rawers, OSSC graduate research assistant, wrote the remainder of this month's Bulletin.

Philip K. Piele
Executive Secretary

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Introduction

Science education is currently the focus of much national discussion reminiscent of the Sputnik era. Fear that the United States is losing its position as world leader in scientific and technological development has initiated concern about preparation by schools of enough students with adequate knowledge and skills to carry on advanced research and development. Reports of declining science achievement tests scores further kindle the debate.

The report of the National Commission on Excellence in Education, A Nation at Risk, released in April, quotes the conclusion of Paul Hurd, educational researcher: "We are raising a new generation of Americans that is scientifically and technologically illiterate." In the same report, John Slaughter, former director of the National Science Foundation, warns of "a growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component."

Thus, the commission recommends:

> The teaching of science in high school should provide graduates with an introduction to: (a) the concepts, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development. Science courses must be revised and updated for both the college-bound and those not intending to go to college.

The National Science Teachers Association (NSTA) launched the

nationwide Search for Excellence in Science Education project in 1981 and recently produced a set of characteristics that are common to successful programs:

- An exemplary program is designed for excellence and most often is initiated by a central office administrator or a master science teacher.
- The program includes several years of focused, intensive, inservice training for teachers.
- The curriculum is developed locally.
- Textbooks are not central to teachers' lesson plans.
- Team teaching is emphasized.
- The science supervisor (or department head) plays a key role in program planning and implementation.
- Strong support exists for the program in the central office and among principals.
- The science program has visible impact on other school programs.
- Close ties are maintained with science educators from local colleges and universities.
- The program constantly evolves.
- The program enjoys strong community involvement and public support.

This month's Bulletin describes the development and the components of the science program at Rex Putnam High School of North Clackamas School District in Milwaukie. The chapters that follow make clear that Putnam's approach to science instruction fulfills the recommendations of A Nation at Risk and also embodies the characteristics of a successful program revealed through the NSTA's Search for Excellence in Science

Development of the Unified Science Course

The cornerstone of Rex Putnam High School's science program is the two-semester required course, entitled "Science 1 and 2," and based upon the unified science approach to science education. David Cox, Putnam's science coordinator, defines unified science as "a tested approach to organizing science learning experiences that emphasizes the development of skills and concepts with broad applicability across the various science disciplines." As such, it provides a solid foundation for later, elective science courses as well as promotes learning that will be of utility to students who elect no more science coursework beyond the required year.

Ten years ago Cox spent a year's sabbatical at The Ohio State University pursuing graduate studies and working at the Center for Unified Science Education headquartered on the Columbus campus. When he returned to Putnam in 1974, competency-based education was beginning to be implemented in Oregon secondary schools. Cox explains that the idea of teaching a required science course structured around science competency areas "just emerged from amongst the science staff" of Putnam. They view competency areas as "existing on a continuum. Each learner arrives in our school somewhere along that continuum, and it is the goal of our instructional program to provide opportunities for continuous progress."

The Putnam staff of seven full time science teachers, six of whom have worked together for the past fifteen years, firmly agree that, if they are to require students to complete only one year of science, they

should not restrict it to content that will be of use in merely one scientific discipline. Besides being applicable in all areas of science, the content should be useful to all students regardless of what they do or study in the future. These seven teachers are firmly committed to the philosophy that through science courses students must come to understand what science is and not simply learn about science.

Agreement with and commitment to this philosophy was a necessary first step for the Putnam science teachers, but, according to Cox, "The catch was--how do you operationalize that kind of approach in a high school when no textbook and no teacher's experience matches it?" The science staff, however, had been introduced to the concept of integrated science through participation in development and piloting of the Portland Project Integrated Science materials. Their solution was to use the knowledge and skills developed through their Portland Project experiences to develop their own locally relevant goals, curriculum, and materials for this required year of science.

Their first task was to generate science program goals to serve as guides for selecting themes around which to organize instructional units and upon which to base competencies. NSTA's position paper "School Science Education for the '70s" and "Program Objectives and Scientific Literacy" from the Center for Unified Science Education served as valuable aids to goal-setting. The latter work culminated three years of research at The Ohio State University that elucidated a core of pervasive science concepts and process skills. Researchers derived a list of twenty-nine concepts used in every discipline of science and fifteen science process skills that are employed in all areas of

science. (All twenty-nine key concepts and fifteen process skills are enumerated in Appendix A.) Besides concepts and process skills, locally relevant natural phenomena and science/society problems were considered as potential organizing themes for the instructional units that Putnam science teachers developed.

Realizing that they could not offer units devoted to all key concepts, process skills, natural phenomena, and science-related problems in a year's course, the staff selected the ones that they agreed were most important and determined that they would do a thorough job of organizing their instructional units around those important themes. After identifying these unit themes, the science staff worked together after school and on Saturdays to enumerate specific, target objectives for each unit. During the summer of 1975 they started actual curriculum construction and completed four of their proposed twelve teaching units. They piloted these four units the very next school year. Summer 1976 saw the completion of all eight remaining units. By that second summer they had perfected their approach and worked together as an efficient team.

Keeping their team-generated objectives in mind, the Putnam science teachers worked at various tasks to complete the units one by one. One member screened audiovisual materials available through the ESD and selected those relevant to the objectives. Another drafted self-checks to accompany each objective. Others screened and selected pertinent activities from science texts and from a wide array of curriculum materials that Cox had obtained from around the country. When they could find no activities already developed to address a particular

objective, they devised and wrote their own materials. A further task was composing final examination questions to test achievement of the unit's objectives.

After several days of work at these individual tasks, members presented their selections and creations to the rest of the team. If all members approved of an activity or an audiovisual aid, it was incorporated into the unit. If anyone expressed misgivings about its value to the unit, it was earmarked as optional only. If team members were unfamiliar with an activity, they tried it out in order to judge its relevance. Usually within another few days the team had decided upon the specific content for the unit at hand and was ready to proceed with work on the next one.

By the start of the 1977 school year, a piloted and revised "Science 1 and 2" were ready for year-long implementation at Rex Putnam High School. Prior to full implementation the science staff shared their creation with Putnam's Curriculum Advisory Committee by explaining the program's rationale and allowing committee members to examine the units. Board members were given two similar presentations plus early evaluation results and a chance to experience several of the learning activities themselves. A further selling point was the project's cost effectiveness. Expenses, which included salaries for teachers' and typists' summer work, printing costs, and purchase of student three-ring binders, amounted to less than the cost of buying typical new textbooks for a year-long course.

Besides being less costly than a text-based course, Putnam's teacher-developed course is more flexible and can be more easily kept up

to date. It is not difficult to devise new units around timely themes and substitute them into the course in place of less relevant ones as teachers see the need. Individual units can also be and are frequently revised by adding or eliminating objectives and by modifying old or substituting new activities. Thus, the course is kept both current and locally relevant.

An example of this flexibility through the incorporation of timely and relevant activities is Putnam's application of microcomputers in the science program. Lance Lechner, who joined the science teaching team six years ago and, thus, is its newest member, supervises students in writing programs that reinforce skills and replace or supplement older activities. Several of these student-authored programs have been incorporated into the required course, as well as into other, elective science courses. These microcomputer programs afford science students the chance to operate a microcomputer independently and to apply it as a tool in scientific investigation.

Description of Science Offerings

Sections of this chapter detail the various courses that comprise Putnam High School's science curriculum. Each section begins with course descriptions excerpted from The Kingsmen: Rex Putnam High School Course Catalog. The unified science course, Science 1 and 2, is afforded more attention here due to its unique, local development at Putnam. The physics, chemistry, and biology sequences employ a somewhat more traditional and college preparatory approach to science education.

The Required Year of Science

Science 1 and Science 2

Science 1 is designed to help students increase their understanding and skills relative to observation, perception, measurement, scientific models, radioactivity, and the cell.

Science 2 begins with the study of genetics and then examines classification, heat energy, and energy. A unit concerned with a mouse colony leads to an increased understanding of genetics, maturation, populations, communities, and ecology.

Science 1 and 2, unified science, provides preparation for later science instruction and also promotes learning of personal usefulness for those students who will not elect formal science study beyond the required level. Multiple learning experiences in multiple science contexts (e.g., physical, biological, earth sciences) are employed in each instructional unit in order to enhance both lateral (across disciplines and from the classroom into the "real" world) and vertical (from one science course to another) transfer of learning. This is

consistent with the theories of contemporary learning psychologists such as Robert Gagne, the unified science approach, and the philosophy of the Putnam science staff.

The Putnam staff chose to construct this course of basically independent instructional units in order to facilitate flexibility and improvement. In designing units they took into consideration what students had already studied and looked ahead to what they would be studying in the future but made sure no one unit was irrevocably tied to another. Thus, it is possible to partially or completely revise or replace a unit without destroying the integrity of the course as a whole.

Due to the diverse backgrounds and teaching styles of Putnam's seven science teachers, each unit is designed so that it can be taught in either a traditional manner with all students doing the same thing at the same time or a semi-individualized approach with individual or small groups of students involved in a variety of activities simultaneously. Each unit includes a rationale, objectives, learning activities, self-checks, and a vocabulary list. Intended to average approximately three weeks of instructional time, each unit is printed complete with an attractive cover page and combined with other course units in a three-ring binder for each student.

Unit Themes

Each instructional unit is organized around one category of unified science themes. In one category are the investigative and interpretive science process skills such as observing, classifying, and measuring. Another group of organizing themes are science concepts common to most

or all scientific disciplines. Among these are perception, model, and energy. Since one of the primary goals of science is the understanding of natural phenomena, this a rich area from which to select unit topics. The Putnam units organized around natural phenomena include radioactivity, the cell, genetics, and mice. A fourth source of unit themes is science/society problems such as land-use planning, genetic engineering, and energy resources. While the present course does not contain any full units organized around this category, the science/society element is present within numerous units.

The twelve units that comprise the first year of science instruction at Rex Putnam High School and their corresponding unified science categories are:

Unit Theme	Unified Science Category
Observation	Process
Perception	Concept
Measurement	Process
Model	Concept
Radioactivity	Phenomenon
Cell	Phenomenon
Genetics	Phenomenon
Classification 1	Process
Classification 2	Process
Heat Energy	Concept
Energy	Concept
Mice	Phenomenon

Rex Putnam High School science teachers prefer unit objectives to overall course objectives. They believe that unit objectives provide a clear focus for learning activities and evaluation while the full collection of unit objectives communicates comprehensively the desired outcomes for the course as a whole. The full year of required science involves 57 objectives. Putnam teachers have found it quite manageable to address four or five objectives during each three-week period.

Unit Rationale

Putnam's science team members believe that students must know why it is worthwhile for them to devote time and energy to studying each unit. Therefore, a half-page rationale introduces each unit. It focuses on both the significance of the unit to science and the value of the learning as applied outside the science classroom in the "real" world. The team believes that a unit without application in both areas cannot be appropriately included in the general education portion of their science curriculum.

For example, the rationale for the unit on observation, "Do You See What I See?" is as follows:

> What we call science is really nothing more than one way in which people attempt to better understand the world they live in. One of its unique features is that it starts with observations of real things--some living, some non-living.
>
> In the game of science, the best observers are usually the winners! However, being a good observer pays off even if you aren't a scientist.
>
> The good observer is able to obtain more information from the environment. It may be the difference between drawing a blank or being successful on a hunting trip. Being a keen observer may assure that the clothes you buy will be the best available on the rack. (Wouldn't it be nice to notice the torn seam or missing button before you arrived home?) Or it may even mean that you will be more successful in science class.

This unit has a number of activities that are designed to help you become a better observer. Among other things, you'll discover that certain types of observations have been found to be more useful than others.

Learning Activites

Since unit objectives were generated independently of any particular set of instructional materials, no existing set was satisfactory for meeting Putnam's unified science needs. A given text, or chapter from a text, may have served as the foundation for a unit, but selected, additional activities from other sources were usually incorporated into it. A surprising amount of material is in the public domain, so Putnam teachers have had few copyright problems. Units built around the themes of observation, perception, radioactivity, the cell, genetics, classification, heat energy, energy, and mice were basically designed around existing materials. Putnam teachers drew heavily from the first year of the Portland Project Integrated Science Sequence but added substantial numbers of new activities, questions, and illustrations. On the other hand, the model unit is an original creation of the Putnam staff and the measurement unit is almost as original.

The staff incorporated a wide variety of learning modes through the activities they selected. It is not unusual for one unit to include from six to ten different types of activities. Among the different learning modes included in the units are reading, lecture, demonstration, discussion, computer-simulated experiment, film, game, programmed instruction, laboratory activity, and slide tape. Approximately 85 percent of student instructional time is devoted to

"hands on" learning activities.

Besides multiple learning experiences, Putnam science teachers included multiple science contexts in their unified science course. They selected activities for each unit from as many different science disciplines as possible. For example, in the unit, "Do You See What I See?" the emphasis is on the process skill observation, which can be applied in many areas of science. Students develop proficiency in the skill itself while also gaining incidental learnings in the science disciplines in which it is applied in the unit.

Self-Checks

A self-check is a short, self-administered evaluation designed to provide immediate feedback to the student about his or her current level of skill or knowledge. There is at least one self-check item for each objective. Criteria are provided that identify minimum acceptable levels of performance, and instructions are given for action to be taken if performance is below an acceptable level. Below is a sample unit objective, performance indicator, and its corresponding self-check.

Objective: Demonstrate a preference for quantitative observations.

Performance Indicator: From a list of observations identify those that are quantitative and those that are qualitative.

Self-Check: Number 1-5 on a piece of scratch paper. Place a "+" by each number whose observation is quantitative and an "0" by each number whose observation is qualitative. When you are finished, check your answers against those found at the bottom of the page.

A student observing an insect collection noted the following:

1. All have 6 legs.
2. All have jointed appendages.
3. Compound eyes are present.
4. Each insect has 3 body segments.
5. The skeleton is on the outside (exoskeleton).

Answers: 1. + 2. 0 3. 0 4. + 5. 0 If you had any problems with these, read the material on page 4. If you still have difficulty or questions, check with your teacher as soon as possible.

Student Evaluation

Students are evaluated on the basis of the degree to which they have achieved the unit objectives. Grades are determined by a point system, with points awarded for laboratory reports, problem-solving assignments, quizzes, and examinations. All of these graded activities are keyed to unit objectives and their corresponding performance indicators. In general, one-half of the total possible points must be earned in order to be achieving at the minimum acceptable level.

Laboratory Activity Materials

No new materials were purchased specifically to implement the unified science course. Although it was not purposely planned that way when the course was designed, this has added to its cost effectiveness. Besides employing standard laboratory equipment that already existed in the science department, additional items were manufactured from readily available supplies such as tin cans and cardboard boxes. These teacher-made materials include devices for measuring reaction time, depth perception, and peripheral vision, as well as tin can calorimeters and a host of small teaching aids (e.g., audio tapes, posters, charts).

Science 1 and 2 classes have been taught by all members of the Putnam science staff. At the present time Jerry Fenton, Lance Lechner, Ken Evans, and Perry Hughs combine to teach the 15 sections.

Science Concepts Course

The Science Concepts courses are designed for students who probably would not succeed in Science 1 and 2 because of the reading level of the Science 1 and 2 materials. They are laboratory science courses covering the major ideas in science with an emphasis on biology. Certain students with other special educational needs may be allowed into the Science Concepts courses as may some students who do not succeed in Science 1 after an honest effort.

Science Concepts 1 and 2 are taught by Paul Boring, who has special expertise in this type of instructional program.

Physics, Chemistry, and Biology Sequence

Science 3 (Physics)

A unit designed to sharpen student skills at practically interpreting laboratory data is followed by semi-individualized units dealing with waves and light. The course then focuses upon the study of motion, utilizing extensive strobe photography as a means of recording the motion.

Science 4 (Chemistry)

Science 4 is the first semester of chemistry. In this course the student will learn the basics of chemistry--how to write chemical formulas, writing and balancing chemical equations, and basic laboratory techniques. This course is designed for any students who desire to enrich their science background.

Science 5 (Physics)

The study of motion started in Science 3 is completed here, with

the motion of everything from automobiles to satellites being part of the content. Other topics include momentum, energy, and beginning electricity.

Science 6 (Chemistry)

Science 6 is the second semester of chemistry. In this course, the student will apply the basics of chemistry to practical applications. The student will study the reasons for chemical behavior and use experiments to learn new scientific concepts. This course is recommended for those students who need a science background for continued study after high school and for those who want to enrich their science backgrounds.

Science 7 (Physics)

Man's development of the atomic model, from the time of the ancient Greeks through today, is the primary focus of this course; laboratory work concentrates on recreating some of the classic experiments that have produced dramatic changes in the model. Another major unit is concerned with nuclear science.

Science 8 (Chemistry)

Science 8 is the third semester of chemistry. In this course the students will increase their understanding of the concepts from Science 6, study the application of the electrochemical cell, study the basic concepts of how atoms bond together to form molecules, and learn the basics of organic chemistry. This course is recommended for students who will need a good background in science for further education.

Science 9 (Physics)

Science 9 is a course designed for students who wish to review and extend the content included in Science 3, 5, and 7. The course will stress reading, problem solving, laboratory activity, and demonstrations consistent with those typically found at the college freshman level. Students planning to complete the Advanced Placement test in physics should find this course to be a valuable component of their preparation.

Science 10 (Chemistry)

The objective of Science 10 is to prepare the student for the Advanced Placement test in chemistry. The student should consult with their counselor in regard to college chemisty credit. The topics will basically be a more quantitative approach to the concepts introduced in Science 6 and 8. In addition, topics such as computer chemistry, intermolecular forces, and biochemistry will be explored. Laboratory experiments and demonstrations will be utilized, when applicable, to give the student a more indepth feeling of each science concept studied.

Biology 1

Biology 1 is a laboratory experience in solving problems about living things. The student will start with cells, progress to organisms, and discover the structures and functions involved in their lives. It is for the student who wants a much deeper look at life than that found in Science 1 and 2. This is an excellent course for the student interested in a career in medicine, forestry, wildlife management, or other related fields.

Biology 2

Biology 2 is a laboratory experience in solving problems about living things. Beginning with the ideas used in Biology 1, the student will explore plants, invertebrates, human anatomy, ecology, and pollution. It includes dissection and field trip and is an excellent course for students interested in a career in medicine, forestry, wildlife management, and related fields.

Biology 3

Biology 3 is designed for three types of students: those who wish to take the advanced placement test for possible college credit, those who want to be better prepared for the fields of medicine and forestry, and those who enjoy biology. When taken with Biology 4, it will prepare the student to take the advanced placement test for college biology. This is a highly detailed course concentrating on: cell structure, biochemistry, mitosis and meosis, genetics, DNA, and physiology. Testing will be one-half essay as is done in the Advance Placement tests and college courses.

Biology 4

Biology 4 is designed for three types of students: those who wish to take the Advanced Placement test for possible college credit, those who want to be better prepared for the fields of medicine and forestry, and those who enjoy biology. When completed it prepares the student to take the Advanced Placement test for college biology. It will include: physiology, botany, invertebrates, vertebrates, and ecology. Testing will be one-half essay as is done in the Advanced Placement test and

college courses.

The Instructors

The four one-semester courses that comprise the physics sequence are taught by David Cox and Ken Evans. Science 3 continues the unified science approach and was similarly developed locally by the teachers. Science 5 is a more traditional high school physics course that is predominantly textbook-based, as is Science 7, which delves into the problems of modern physics. Science 9 will be offered for the first time this school year. It will serve as a review and expansion of topics covered in the first three physics courses and will involve topics and materials normally utilized in first-year college physics.

Jack McGoldrick and Ken Evans teach the four-semester chemistry sequence of Science 4, 6, 8, and 10. These courses are primarily laboratory-oriented and are based upon teacher-designed units and activities as well as textbooks. Students who take Science 10, advanced chemistry, use a college-level textbook.

The four biology courses are taught by Paul Boring and Jerry Fenton. Biology 1 and 2 students are aided by the Holt biology text, Modern Biology. Advanced students in Biology 3 and 4 study first-year college topics.

Natural History

Natural History

Natural History is the study of natural objects and organisms and their origins and interrelationships. Students have the chance to study topics such as birds, geology, and mammals. Within the areas studied,

students have the opportunity to choose projects for indepth study and research. The course includes field experiences as well as library research.

Perry Hughes, veteran Putnam science teacher and experienced field biologist, teaches this project-oriented course. Although most students who enroll in Natural History do so as ninth-graders, the class is open to students from all four grades. Some students even elect this course each of their four years at Rex Putnam High School. They gain experience in data collection, taking field notes, and keeping observation logs. Thus, the course affords the student with a very specialized interest in science an opportunity for indepth, guided study at his or her own pace. Hughes ensures these students the chance to showcase their project outcomes for teachers and classmates at the same time that they earn high school credit for disciplined pursuit of their special interest.

Impact and Evaluation of the Science Curriculum

Putnam's science team has solicited student feedback regarding the impact of their unified science course and has used the results in revision and improvement. During the first years of course implementation all students completed unit evaluation forms that allowed the team to determine students' preferred learning activities, their level of interest in the various units, and their judgments regarding the value of each unit and pace of instruction. The team relied heavily upon this feedback during early, evolutionary stages of course development.

Once the course was well-established, 50-question pretest and posttest assessments were introduced into Science 1 and 2. Teacher-developed test items directly measured attainment of all unit objectives. Results of the Science 1 1978-79 test administrations are indicative of their findings. Pretest results produced a nearly normal distribution of raw scores with a mean of 18.67 and standard deviation of 5.11. Posttest results produced a skewed distribution with mean of 27.74 and standard deviation of 7.31. Besides being used to demonstrate marked student growth toward attainment of overall course objectives, the test results were analyzed for each instructional unit. These unit analyses served as the basis for dramatic learning activity revisions to affect increased and more acceptable posttest mean scores in all units.

David Cox's doctoral dissertation studies in 1981-82 confirmed the earlier pretest and posttest findings. He looked specifically at changes in students' grasp of science process skill objectives and

retention of process skills throughout their high school careers after completion of Science 1 and 2. He found statistically significant increases ($p \leq .05$) from pretest to posttest in each of the process skills measured and effect sizes ranging from 0.68 to 0.74 for the combined scores. He detected no significant decrease ($p \leq .05$) in process skill competencies throughout students' remaining high school years regardless of whether they elected more science coursework. Further, he found a significant increase ($p < .001$) in process skill competency beyond Science 1 and 2 for those students who did elect one or more years of additional science study.

Impact upon overall enrollment in science courses serves as a further evaluation of a science program. Despite a generally declining student population, more sections of science classes are filled at Rex Putnam High School this school year than ever before. Thirty-seven sections are being offered, while two more had to be cancelled due to lack of available classrooms. The science team directly credits the popularity of their entire selection of elective classes to the unified science foundation provided in Science 1 and 2. The success of the entire science program confirms and reinforces their continued commitment to offering a required, beginning science course that encompasses the most worthwhile, pervasive concepts underlying all science disciplines.

Galen Spillum, Rex Putnam High School principal and a former science teacher himself, points to the fact that most Putnam students take two and a half years of science as an indication of the program's success. He attributes the program's popularity among students to its

laboratory activity orientation. More than being popular favorites among students, Spillum explains that Putnam's science courses adequately prepare students for work in industry and for college. Putnam administrators hear this commendation repeatedly on their annual Oregon State and University of Oregon campus visitations when they seek feedback from former Putnam students.

Nancy Thornton, former full-time science teacher and eleven-year veteran substitute teacher in the Milwaukie area, emphasizes the quality of Putnam's required year of science. She lauds the team for their creation of a course that "truly cuts across the many different science disciplines at the same time that it imparts to students what science is all about." Thornton, whose son is a senior taking advanced science classes at Putnam High this year, attributes high enrollment in advanced classes to the solid base students gain in Science 1 and 2 and to the expert teaching skills employed by team members in both the introductory course and their specialized elective classes. She views Putnam's program as a "success-oriented" approach to science instruction through which students of all ability levels receive positive reinforcement for honest efforts.

Science teaching team members have seen benefits accrue to themselves as teachers as well as to their students as byproducts of the local development of the unified science course. Since they all had a hand in planning and implementing the curriculum and they all teach or have taught sections of Science 1 and 2, they are fully aware of the skills and concepts that all students acquire. Rather than having to develop these understandings anew in each subsequent science course,

teachers can incorporate and extend these common skills and concepts in more specialized and advanced contexts.

Perhaps the most significant byproduct of their collaborative efforts has been the evolution of a true teaching team. Besides creating their own curriculum, the team's collaborative approach has led to a common grading system and common, consistent standards that they expect students to meet. For example, they all require of students the same standard laboratory report format.

Rex Putnam High School's seven science teachers act as consultants to one another. They observe and assist one another and often devote preparation periods to working in one anothers' classrooms. Thus, they do not teach in isolation, nor are they protective of particular classrooms and laboratory equipment.

They have extended their integrative efforts to instructional planning with other departments in the high school. For instance, they have coordinated with the mathematics department in teaching graphing techniques, which are utilized extensively in science laboratory experiences. They have consulted with language teachers to ensure that science assignments involving reading and writing are consistent with language arts teachers' expectations. David Cox is currently working with social studies teachers toward a more standard set of terms to be used in both departments for describing economic and scientific models.

Replication of the Unified Science Curriculum in Other Schools

David Cox, Putnam's science coordinator, points to the actual process of local science program development as the key ingredient in its success. He views this process whereby teachers themselves decide what themes, objectives, activities, and materials are appropriate for their particular students, in their facilities, and with their own staff as having overriding implications for a lasting implementation of the program. He realizes, though, that it is extremely difficult for a staff to "start from scratch" with the process of local program development. The Putnam team has assisted several other high school science staffs in developing their own programs and has helped train others in the use of Putnam's materials.

Teachers and administrators from other districts frequently visit Rex Putnam High School to observe the unified science program in operation. These visitors are often looking for a better approach to the required year of science instruction or for a more flexible format that will allow new and changing emphases to be incorporated. Putnam's staff members oblige these visitors by "talking them through Science 1 and 2," as Cox puts it. For example, a science staff member from Los Gatos, California, visited for a week during the spring of 1982 and absorbed much of Putnam's program. Putnam's Jerry Fenton then traveled to the Los Gatos school site and helped the science staff build equipment and prepare for one semester of unified science. A Los Gatos teacher returned to Putnam in January 1983 for more indepth training and preparation for the second-semester course. Cox is pleased that the

Putnam staff can help other districts such as Los Gatos through sharing of instructional materials and training of teachers. He projects that Los Gatos teachers will revise and add to the units as they use them and, thus, gain increasing "ownership" of the program.

Another school that fashioned its unified science course after Putnam's program is Salem's McKay High School. McKay's principal and science department chairman visited Putnam before the Salem school began operations. After science teachers who subscribed to the unified science philosophy had been hired at McKay, they developed a course based upon Putnam's Science 1 and 2. Cox provided materials and assistance to them as they selected themes, adapted existing materials, and developed some of their own units.

Sandy High School science staff employed yet another approach to developing a unified science course with assistance from the Putnam team. The Sandy district contracted with the Division of Continuing Education (DCE) to offer an indistrict course, "Unified Science Curriculum Development." Members of the Putnam staff led Sandy teachers through the developmental process. Sandy teachers created instructional units as DCE class projects and then continued and completed the unified science course preparations during the following summer.

Regardless of whether another school decides to develop its own unified science curriculum or to adapt Putnam's program, Cox stresses that the decision must come from within the staff itself if the implementation is to be a success. Such an instructional approach cannot be imposed upon a staff. Instead, teachers themselves must first subscribe to and be committed to its underlying philosophy.

Several of Cox's recommended considerations for local science curriculum development are listed in Appendix B.

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Summary

Rex Putnam High School's science curriculum is firmly based upon an introductory, required, unified science course that the seven-member science team devised and implemented some seven years ago and continue to revise and improve today. More than a survey or general science class, their creation does not focus on one single science discipline at a time but upon concepts and processes that pervade all disciplines of science. Designed to develop science literacy among all students, whether they are college-bound or not, Putnam's unified science course serves both groups of students equally well. Through this course the science teachers believe they teach what science is all about plus build a solid foundation for additional, elective science studies.

Beyond this required course Putnam's science department offers an extensive and rigorous curriculum in physics, chemistry, and biology. The science teaching team interprets the large proportion of students electing to pursue additional science study as a positive evaluation of their introductory, locally developed program of unified science.

David Cox sums up his feelings about their teaching atmosphere: "I couldn't teach in a better place in America than right here in this high school. We've been able to develop our own curriculum, to evaluate it, and to develop a true science team. We have a good spirit. The administration has been supportive, and we have outstanding young people in our school. In other words, I can see nothing negative in our situation."

Interviews

Paul Boring, science teacher, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

David Cox, science coordinator, Rex Putnam High School, Milwaukie, Oregon. Interviews June 3 and August 18, 1983.

Ken Evans, science teacher, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

Perry Hughes, science teacher, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

Lance Lechner, science teacher, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

Jack McGoldrick, science teacher, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

William Olund, guidance director, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

Galen Spillum, principal, Rex Putnam High School, Milwaukie, Oregon. Interviews June 3 and September 6, 1983.

Ray Theiss, science education specialist, Oregon Department of Education, Salem, Oregon. Interview May 28, 1983.

Nancy Thornton, substitute science teacher and parent, Rex Putnam High School, Milwaukie, Oregon. Interview August 23, 1983.

Kathleen Winthers, curriculum director, Rex Putnam High School, Milwaukie, Oregon. Interview June 3, 1983.

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Appendix A

List of Key Concepts and Process Skills

The key concepts of science are:

1. cause-effect
2. change
3. cycle
4. energy-matter
5. entropy
6. equilibrium
7. evolution
8. field
9. force
10. fundamental entities
11. gradient
12. interaction
13. invariance
14. model
15. orderliness
16. organism
17. perception
18. probability
19. population
20. quantification
21. replication
22. resonance
23. scale
24. significance
25. symmetry
26. system
27. theory
28. time-space
29. validation

The processes of science are:

1. classifying
2. communicating
3. controlling variables
4. defining operationally
5. designing experiments
6. formulating models
7. hypothesizing
8. inferring
9. interpreting data
10. measuring
11. observing
12. questioning
13. predicting
14. using numbers
15. using spacetime relationships

Source: Showalter, Victor, in collaboration with David Cox, Paul Holobinko, Barbara Thomson, and Mike Orieda. "Program Objectives and Scientific Literacy," Prism II, Vol. 2, Nos. 3 and 4.

Appendix B

Considerations for Local Science Curriculum Development
by David Cox

Don't try to implement curriculum development from the top down; experience suggests that teachers will use most effectively the course materials that they have developed or adapted to student needs as they perceive them.

Don't expect teachers to know how to develop curriculum without direct instruction before beginning the task.

Set specific production goals (number of units, specifications for the units) with the participants.

Write goals and instructional objectives before beginning the actual development and sequencing of materials and activities.

Select learning activities after unit objectives have been set. However, some activities will lead to the addition, modification, and/or deletion of objectives. The process of selecting learning activities actually refines the objectives.

If the curriculum development project involves day-long released time or summer work, the selection of unit themes and setting of unit objectives should be completed prior to the extended work sessions. If substantial time outside the normal staff meetings is required to complete these tasks, compensation should be provided. The most cost-effective use of extended work time is for activity selection and evaluation.

Use existing activities whenever possible. Original writing is very time-consuming.

Complete the development of units and preparation for activities before trying to teach them. Partially completed units are difficult and frustrating for teachers and students to use and may result in negative teacher and student attitudes toward the course.

Include methods for providing regular feedback to students about their progress as a part of course materials.

Invest in attractive print reproduction for materials. The cost involved in quality typing and reproduction will be repaid in student and staff feeling that the project is important enough to warrant the extra effort and funding.

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